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EQUIPMENT AND METHODS FOR SORTING INSECTS BY SEX

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Releasing sterile insects of only one sex may be more effective for controlling native populations than releasing sterile insects of both sexes (Knipling 1964).[3] In addition, the separation of insects by sex before they emerge into adults will prevent prerelease mating, thus allowing release of virgin insects. Damage caused by female insects, such as biting by the female mosquito or oviposition damage by some insects, is avoided when only males are released.

This is a report on: (1) The development of a sizing machine and its effectiveness in separating codling moths in the pupal stage by sex; and (2) studies conducted with other machines that utilize differences in physical characteristics of adult insects for separation by sex.

METHODS AND MATERIALS

Pupal Separation: The principle employed in mechanically separating pupae by size with the roll separator is based on differences in pupal diameters. To be practical, separating must be at a high rate of speed, accurate, and not injurious to the insect.

The flow pattern in separating pupae starts at a supply hopper (*A*, fig. 1). The pupae are fed out of the bottom of the hopper through a gate opening onto an inclined vibrating trough (*B*, fig. 1). From here the pupae drop onto two closely spaced inclined rotating rolls (*C*, fig. 1) that counterrotate upward to keep the pupae in a single line. The space between rollers increases from top to bottom. Pupae fall downward between the rolls, where the roll clearance is as large as the insect, into collecting pans (*D*, fig. 1).

Adjustments of feeding rate for separation include a slide gate on the hopper and a control for vibration of the trough. Maximum separation rate is limited because insects must be kept in a single line between the rolls. Roll clearance adjustments at each end of the rolls are provided to select the desired separation. The smallest pupae drop into pan No. 1 and the largest into pan No. 10. (*D*, fig. 1). Pupae of intermediate sizes drop into the other pans where clearance first becomes sufficient as they slide down the incline. The maximum free fall of pupae from center of separating rolls to tray is 6 inches.

Physical dimensions and specifications of the machine are shown in plates 1 through 11. The rolls were made of steel tubing, 4 inches outside diameter and 60 inches long. Cold-finished extruded tubing was used to obtain the maximum degree of concentricity of inside and outside diameters and thereby minimize problems in dynamic balancing. Bearing housings were shrunk fit into both ends of the rolls and a V-belt groove was cut in the housing at one end of each roll. The rolls were then turned to 0.003 inch total indicator runout through their full length,

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[3] Knipling, E. F. The potential role of the sterile method for insect population control with special reference to combining this method with conventional methods. U.S. Dept. Agr., Agr. Res. Serv. ARS 33-98. 54 pp. 1964.

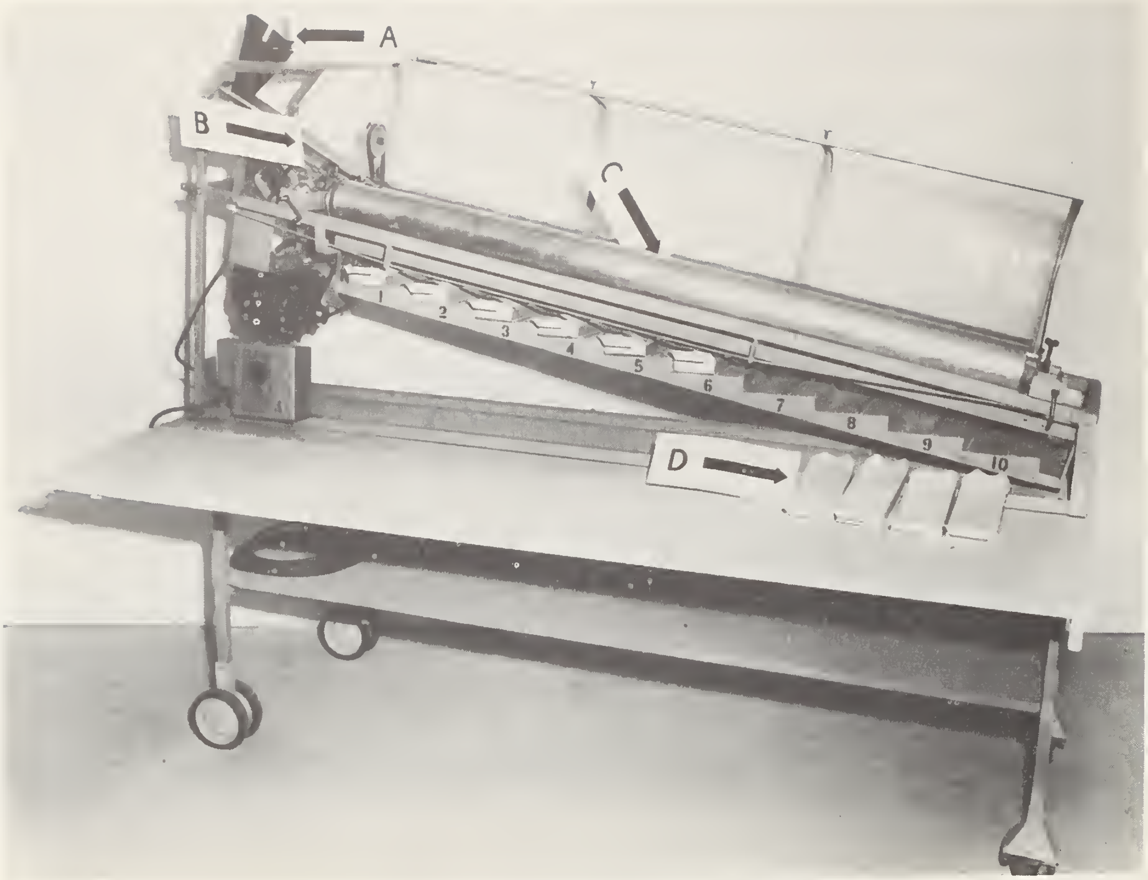

Figure 1.–Inclined roll sorter for separating insect pupae by size: A, Supply hopper; B, inclined vibrating trough; C, inclined rotating rolls; D, collecting pans for insect pupae.

ground to a surface smoothness of 16 micro-inches, and plated with 0.002 inch of cadmium. Ball bearings were pressed into the housings and the assembled rolls mounted on nonrotating shafts and dynamically balanced to turn without vibration at speeds up to 1,000 r.p.m.

The rolls were mounted on the sorting machine at an incline of 10° angle with the horizontal and driven at 280 r.p.m. by a 1/3-horsepower electric motor. Clearance between rolls was adjusted to collect all pupae in pans No. 1 through No. 10, with approximately 50 percent of the pupae in the first five pans. During operation, the rolls were kept clean by periodically swabbing with carbon tetrachloride to remove all dust and other foreign material.

Naked laboratory-reared codling moth pupae produced on a diet of green apples were used in the separation tests. After the pupae were sorted by machine, the sexes of each group were determined visually to check the accuracy of separation.

Adult Separation: Mechanical separations of adults were based on one or more differences in physical features of the adult codling moths. These physical features included insect thickness, length, density, surface texture, shape, and response to an electrostatic charge. The devices used for these studies are shown in figures 2, 3, 4, and 5[4] and are described more fully by Harmond, Brandenburg, and Klein.[5]

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[4]Photographs and equipment for tests furnished by J. E. Harmond, Agricultural Engineering Research Division, Agricultural Research Service, U.S. Department of Agriculture, Corvallis, Oregon.

[5]Harmond, J. E., Brandenburg, N. R., and Klein, L. M. Mechanical seed cleaning and handling. U.S. Dept. Agr. Handbook 354, 56 pp. 1968.

The perforated round-hole screen (fig. 2) has 0.113-inch-diameter openings and utilizes differences of insect thickness (dorsal to ventral dimension) for separations. Cooled, immobile adults to be separated were placed on the screen. The screen was agitated by holding it on a plate vibrator for 5 seconds. The agitation of the screen was sufficient for the small insects to fall through the holes into a catch pan beneath the screen while the large insects remained on top.

The perforated slotted-hole screen (fig. 2) has 0.094-inch by 0.75-inch holes and utilizes differences of insect breadth (lateral dimension) and length for separations. The procedure in using this screen for separation tests was the same as that for the round-hole screen.

The air-gravity separator (fig. 3) utilizes differences of insect density for separations. The separator operates on the principle that insects having a low density will be lifted, while insects having a high density will fall in an airstream.

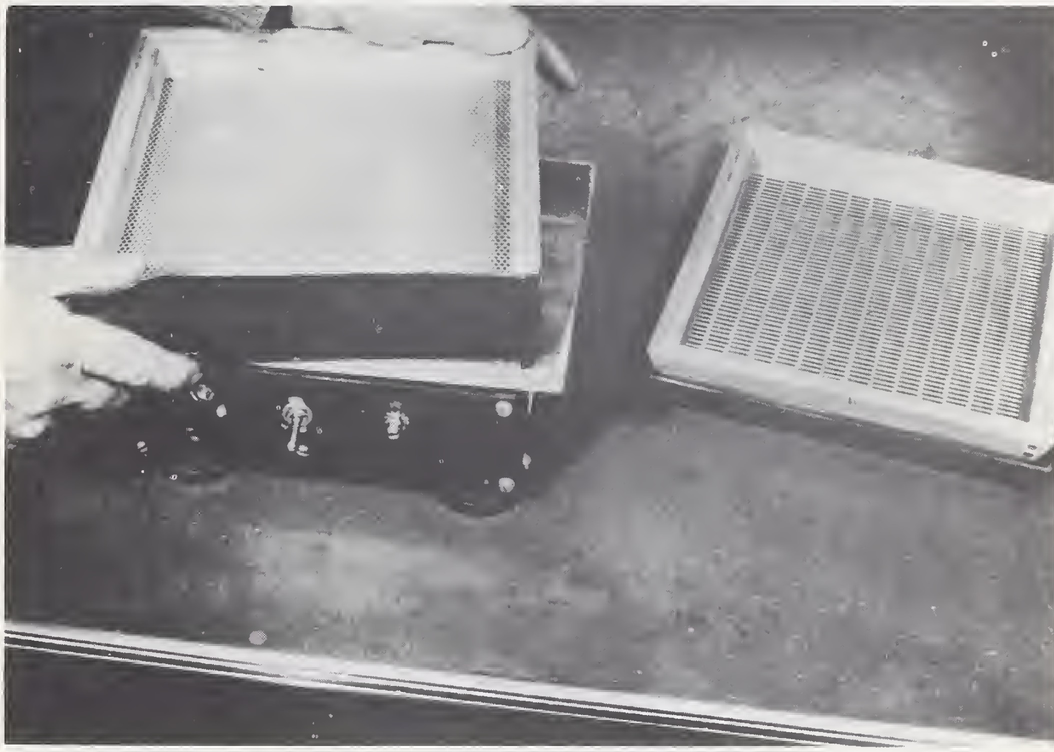


Figure 2.—Round-hole and slotted-hole screens for use on vibrating table.

The air-gravity separator (fig. 3) includes a blower with drive motor and adjustments to change the air output for insect separation. Insects that are injected near the center of the air column are subjected to vertical air movement. The light insects are blown out the top of the column into a collecting pan. The heavy insects fall onto a sloping screen, out the small opening on the side of the column, into a pan.

The electrostatic separator (fig. 4) utilizes differences in charge of insects for separation. Cooled, immobile insects are fed onto a moving endless belt. As the belt moves downward around a pulley, the insects fall off into collection pans below. A probe with a 20,000-volt charge emits an electrostatic field in the area where the insects are dropped from the belt. This field attracts some insects more than others. The nonuniformity of attraction causes the insects to fall at different locations. Adjustments of the electrostatic field and the deflecting baffles above the collecting pans provide for more effective separations.

The vibrating inclined table separator (fig. 5) utilizes differences in insect surface texture and shape for separation. Cooled, immobile insects are fed from the hopper and vibrating trough onto an inclined vibrating table.

Figure 3.—Air-gravity separator.

Vibration of the table causes the insects to move along different paths toward the dividers and collecting pans. Adjustments in stroke of table vibration, inclination of table, rate of feed, divider placement, and table surface composition, all influence separation of the insects. A fine sandpaper surface on the table was used for these tests.

Adult codling moths used in the separation tests were laboratory reared. One lot was reared on an artificial diet while others were reared on green apples. Some adults were stained with red Eosin Y dye.[6] The adults were kept slightly below 40° F. in an insulated container with ice until about 2 hours before separation tests. The insects were then subjected to 32-33° F. to make them immobile.

[6]Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

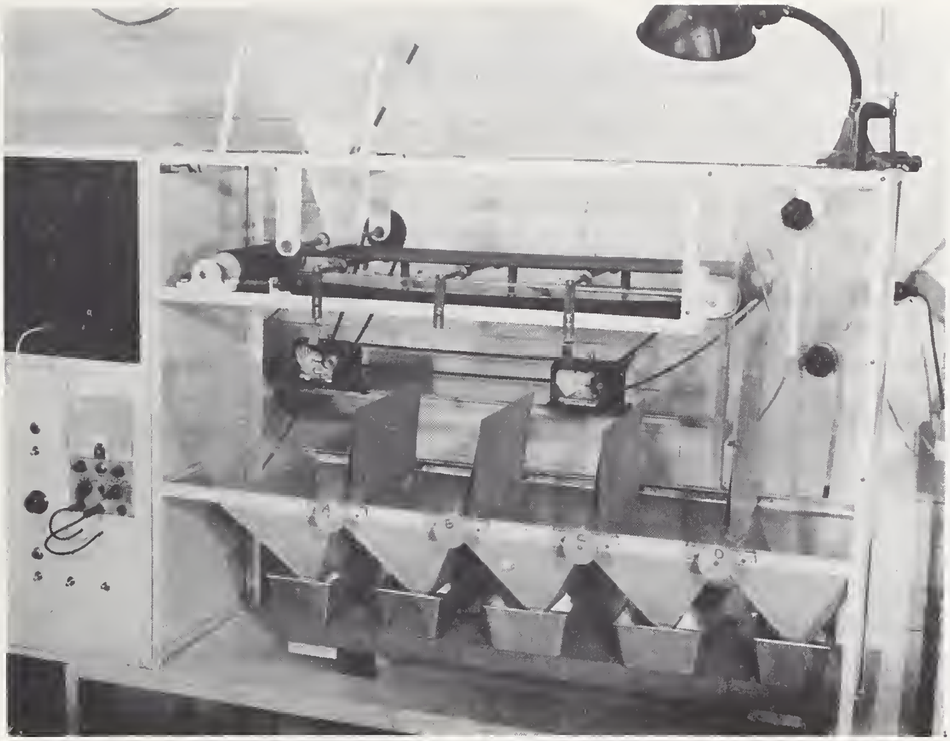


Figure 4.–Electrostatic separator.

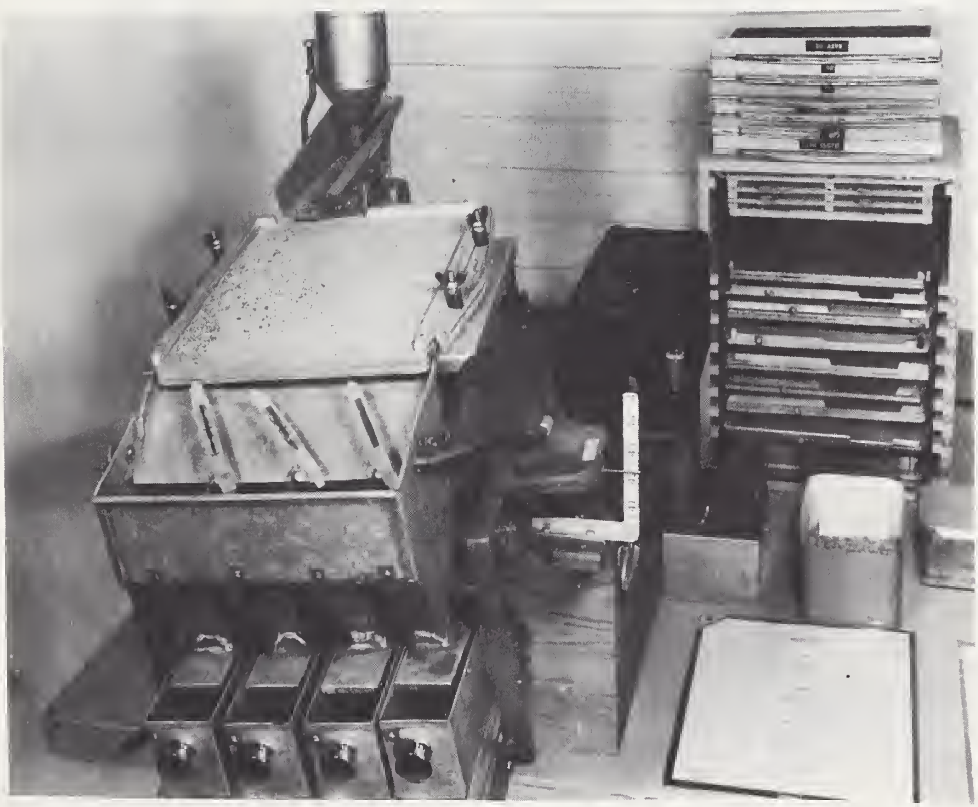


Figure 5.–Vibrating inclined table separator.

The separation tests were replicated five times, using five males and five females per lot. Only one separation test of any one lot of insects was made in order to minimize injury. The condition of the insects after the separation tests was determined by visual observation.

RESULTS AND CONCLUSIONS

Pupae Separation: Re-sorting a particular lot of codling moth pupae, using the separator shown in figure 1, did not materially affect changes in percentage of sort. The most effective sorting of all pupae was obtained with a clearance of 0.088 inch at the top end of the rolls, above pan No. 1, and 0.121 inch clearance at the lower end of the rolls, above pan No. 10, a difference in clearance between extreme ends of the rolls of 0.033 inch.

Separation of a representative lot of pupae is shown in figure 6. The top graph represents the relationship between adult males and females for each pan. (The pans are indicated from 1 through 10). All insects collected in pan No. 1 were male, and all insects collected in pans No. 9 and No. 10 were female.

The lower left graph represents the percentage of the total male pupae collected in each pan and the cumulative percentage of the male pupae starting with pan No. 1. All of the male pupae were collected in the first 8 pans. Pan No. 5 contained the largest number of male pupae.

The lower right graph represents the percentage of the total female pupae collected in each pan and the cumulative percentage of the female pupae starting with pan No. 10. All of the female pupae were collected in pans No. 2 through No. 10.

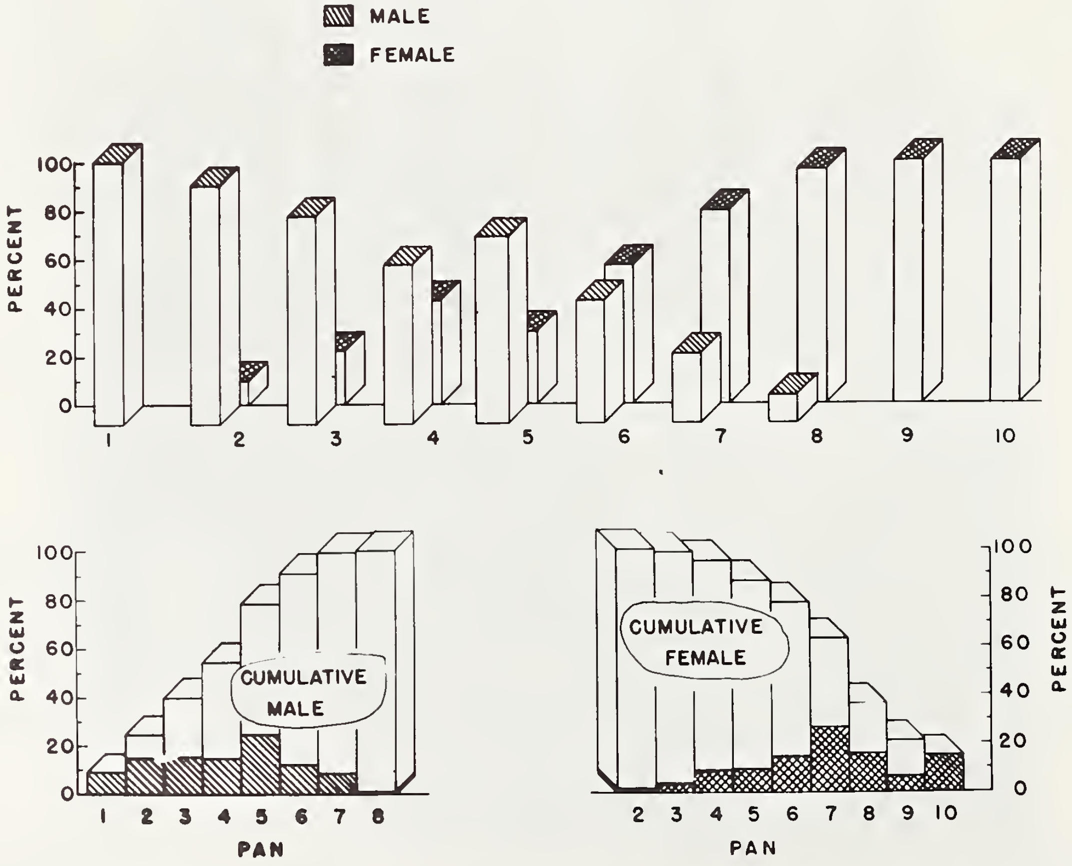


Figure 6.–Mechanical separation of codling moth pupae with roll sizer.

Pan No. 1 contained only male pupae, or 9.6 percent of all the male pupae.

Pans No. 9 and No. 10 contained only female pupae, or 21.1 percent of all the female pupae.

Pans No. 1, No. 2, and No. 3 contained 40 percent of the male pupae and 4.9 percent of the female pupae.

Pans No. 8, No. 9, and No. 10 contained 36.5 percent of the female pupae and 0.7 percent of the male pupae.

Healthy female codling moth pupae are larger than the male pupae. The pupae used in these separation tests were reared in a laboratory where some diseases existed. These diseases may have caused more than the normal amount of overlapping in size of the sexes.

This inclined roll separator will separate codling moth pupae and other similar insects to a precise size difference. It will also separate the pupae effectively by sex when the size of all insects of one sex is different from that of the opposite sex and when the proper roll clearance is used.

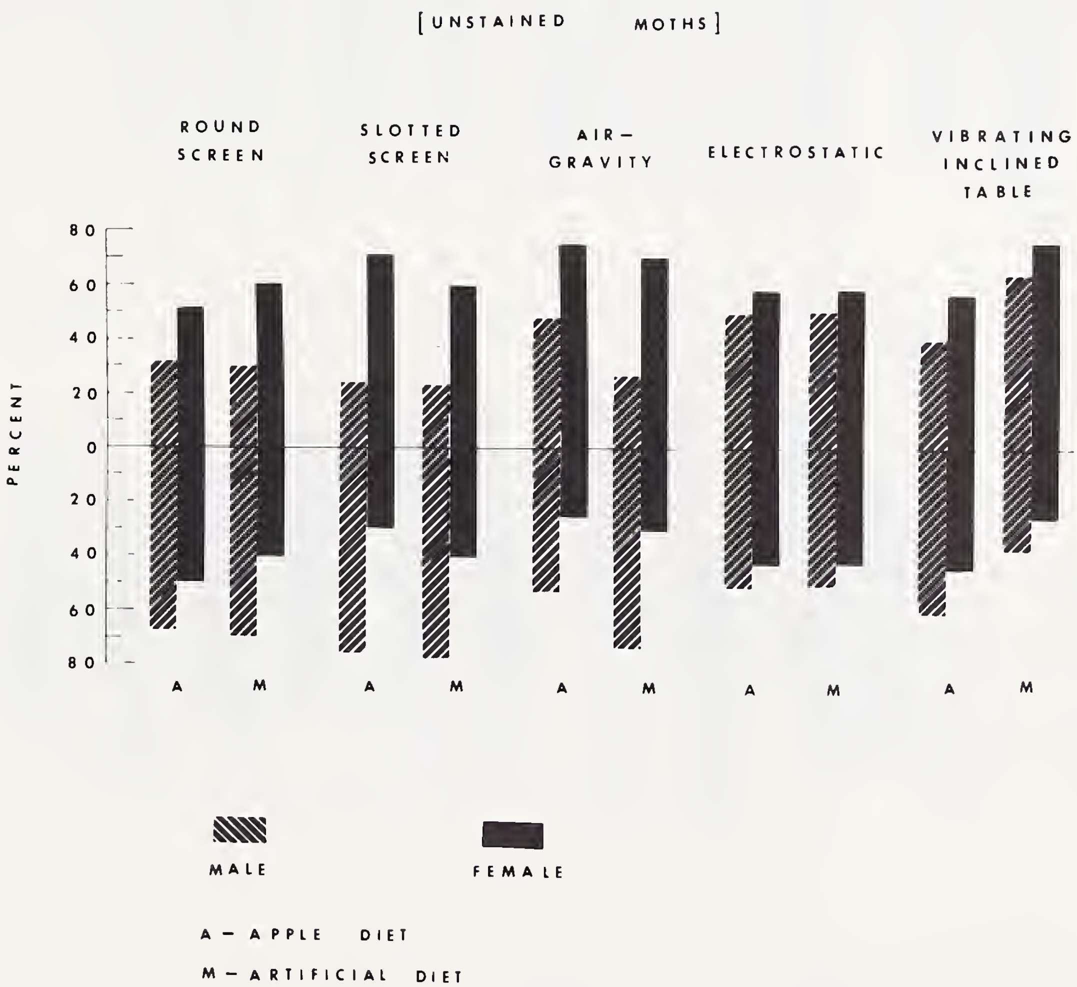


Figure 7.—Separation of unstained adult codling moths by sex.

Adult Separation: Attempts to separate adult codling moths by sex with the machine shown in figure 1 were not successful. This was partly a result of using diseased laboratory-reared moths that did not develop normally.

Early investigations using either faster roll speed or greater angle of rolls increased feed rate but resulted in less effective separation of insects by sex.

Comparisons of the results of separating adult codling moths by the five different devices shown in figures 2, 3, 4, and 5 are shown in figures 7 and 8. The percentage of moths, both male and female, represented above the zero line for both the round screen and the slotted screen denotes those moths remaining on the screens, whereas the percentage represented below the zero line denotes those that fell through the screens. The lightweight moths lifted by the air-gravity separator are represented above the zero line, whereas the heavier moths are represented below. The moths showing the least attraction to the electrostatic charge during separation are represented above the zero line, whereas those showing strongest attraction are represented below. Moths that moved the least distance on the inclined table are represented above the zero line, whereas those that moved the greatest distance are represented below.

During the separation tests, wing scales were knocked off the insects by the separating devices. The condition of the moths as determined after each separation test (fig. 9) was based on an arbitrary scale of 1 through 5. The smaller the number, the worse the condition of the moth. Thus, a moth with a rating of 5 would have no apparent loss of wing scales.

The most effective separation by sex was with the slotted-hole screen for stained insects reared on artificial diet. In this separation 80 percent of the male and 16 percent of the female moths passed through the screen (below

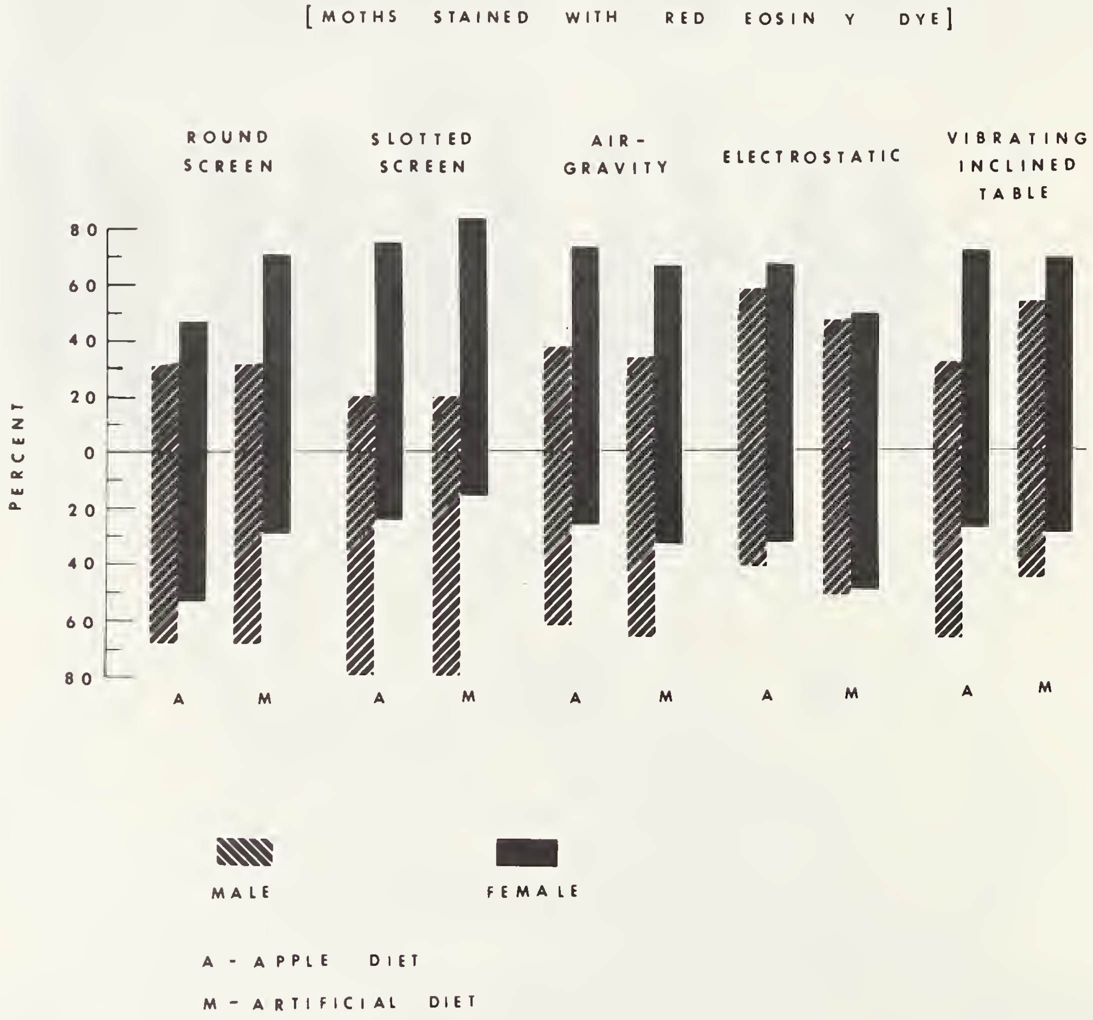


Figure 8.–Separation of stained adult codling moths by sex.

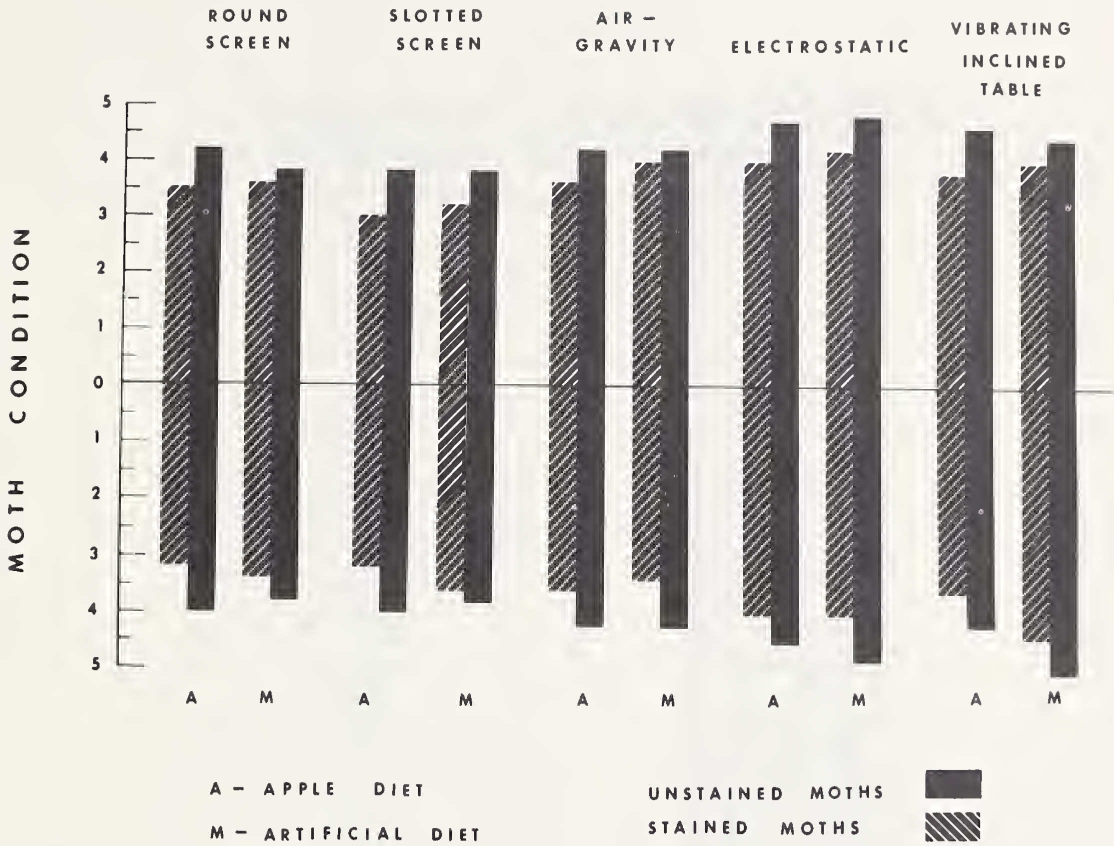


Figure 9.–Physical condition of adult codling moths after separation by various methods.

zero line, fig. 8). However, the insects separated with the slotted-hole screen and with the round-hole screen were in slightly worse condition, having lost more wing scales, than insects separated with other separators.

The poor condition of the adult moths after the tests may partly be attributed to transportation of the insects over 600 miles by automobile, before separating.

In general, the least effective separation of adult moths was obtained with the electrostatic and vibrating inclined table separators.

No significant differences in separation of insects by sex existed with any one particular separator on insects fed on artificial diet or apple diet, nor between stained and unstained insects.

SIZING MACHINE

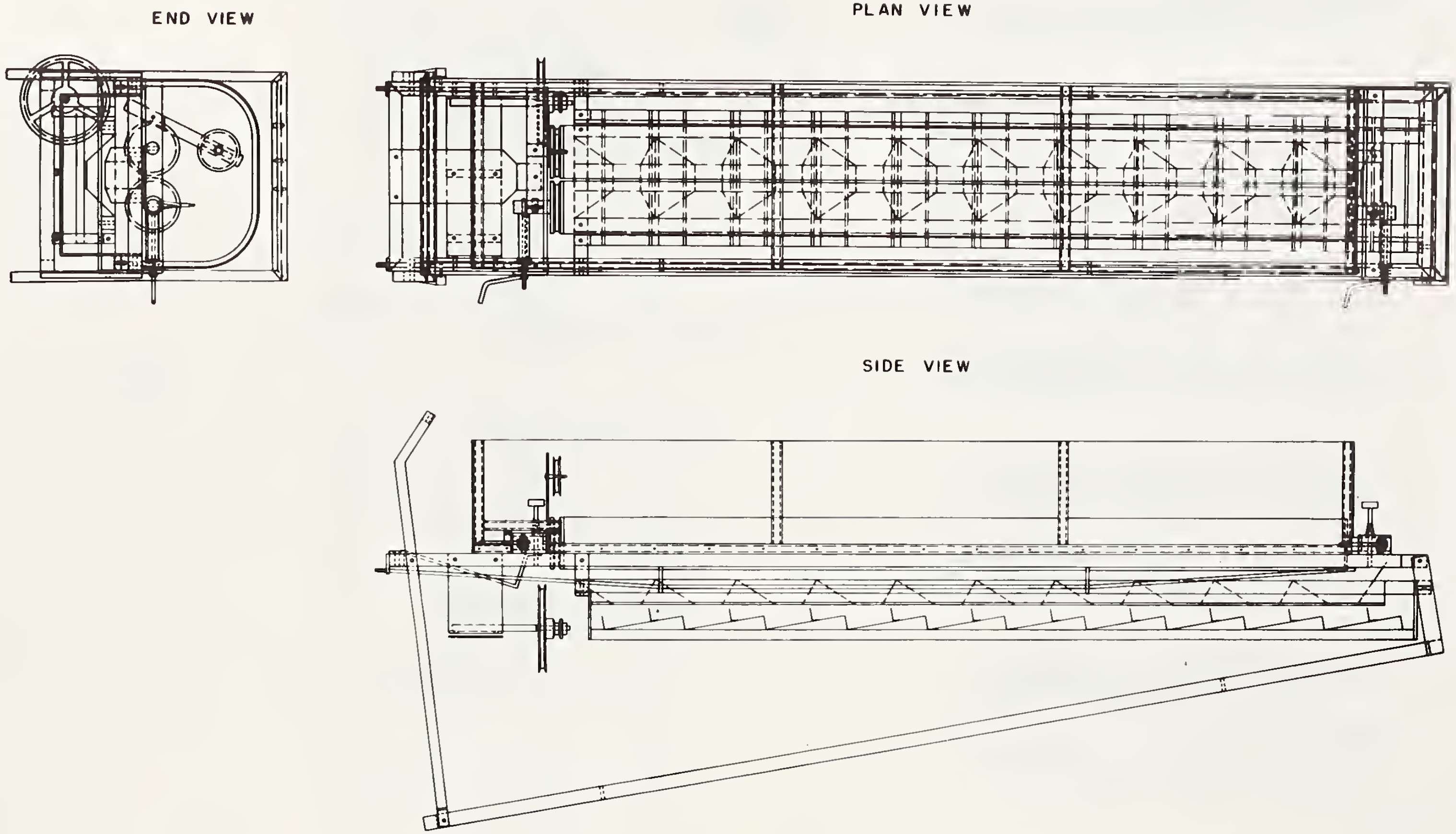
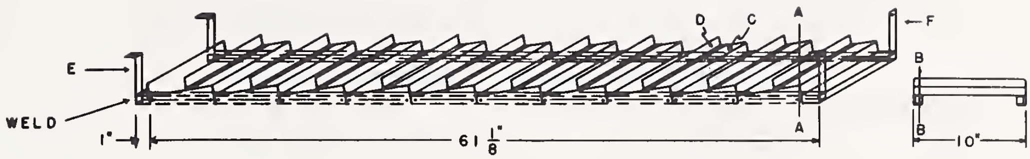
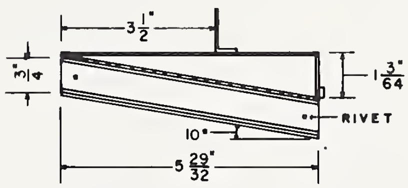


PLATE 1

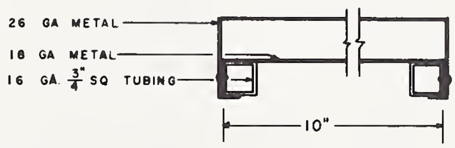
TRAY FRAME



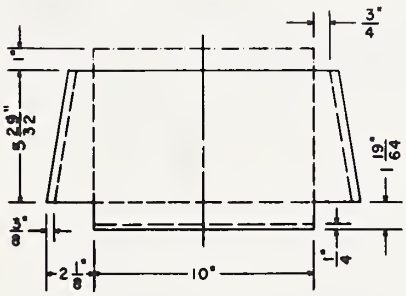
CROSS SECTION BB



CROSS SECTION AA



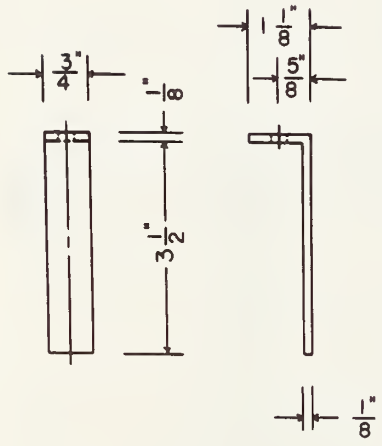
PATTERN C



PATTERN D

PLATE 2

PATTERN E



PATTERN F

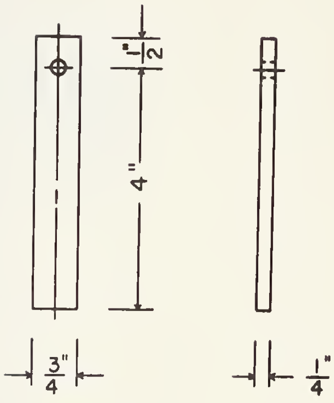


PLATE 2A

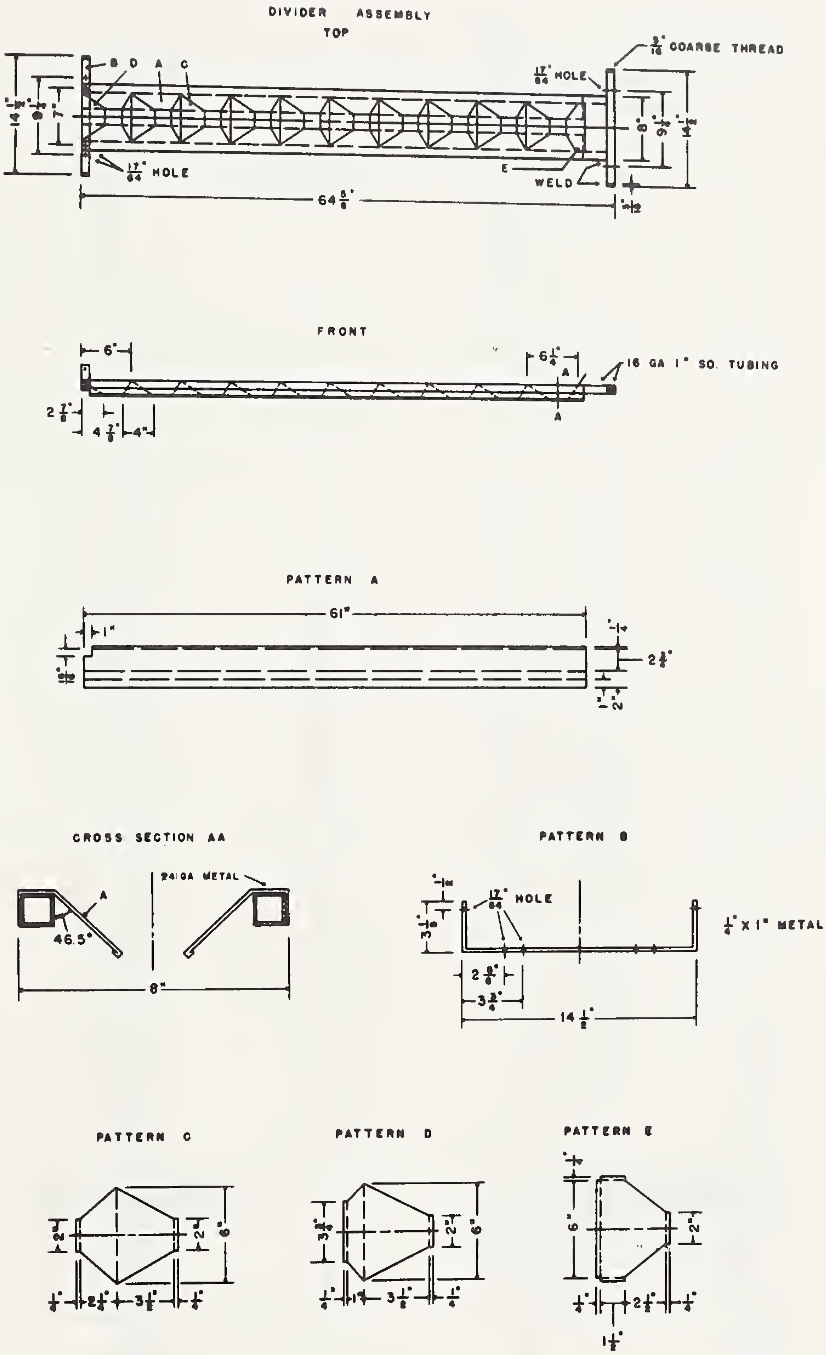
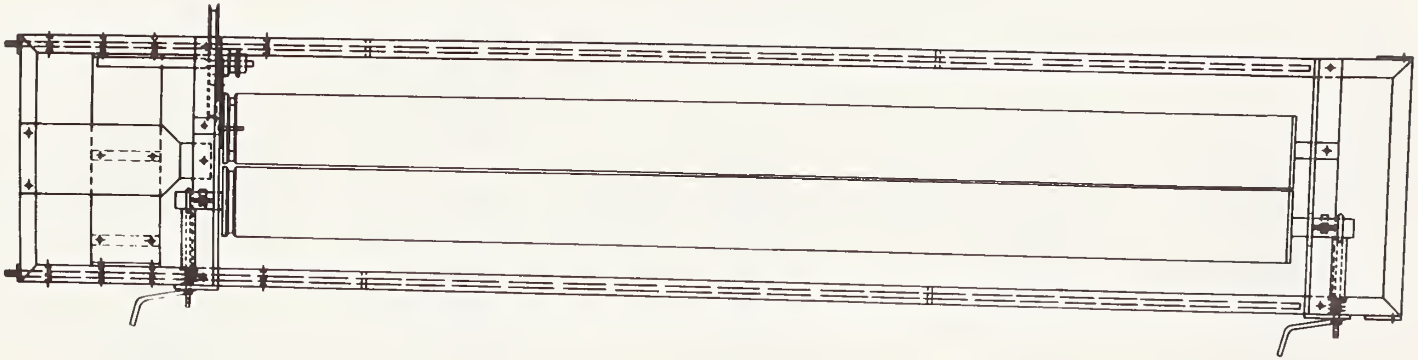

DIVIDER ASSEMBLY
TOP
COARSE THREAD
HOLE
HOLE
WELD
FRONT
16 GA 1" SQ. TUBING
PATTERN A
61"
CROSS SECTION AA
24 GA METAL
46.5°
8"
PATTERN B
HOLE
METAL
PATTERN C
PATTERN D
PATTERN E

PLATE 3

PLAN VIEW



SIDE VIEW

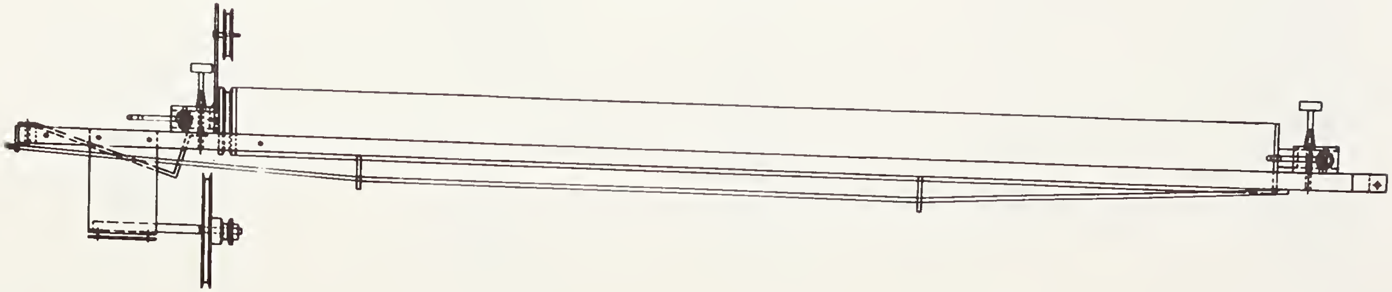


PLATE 4

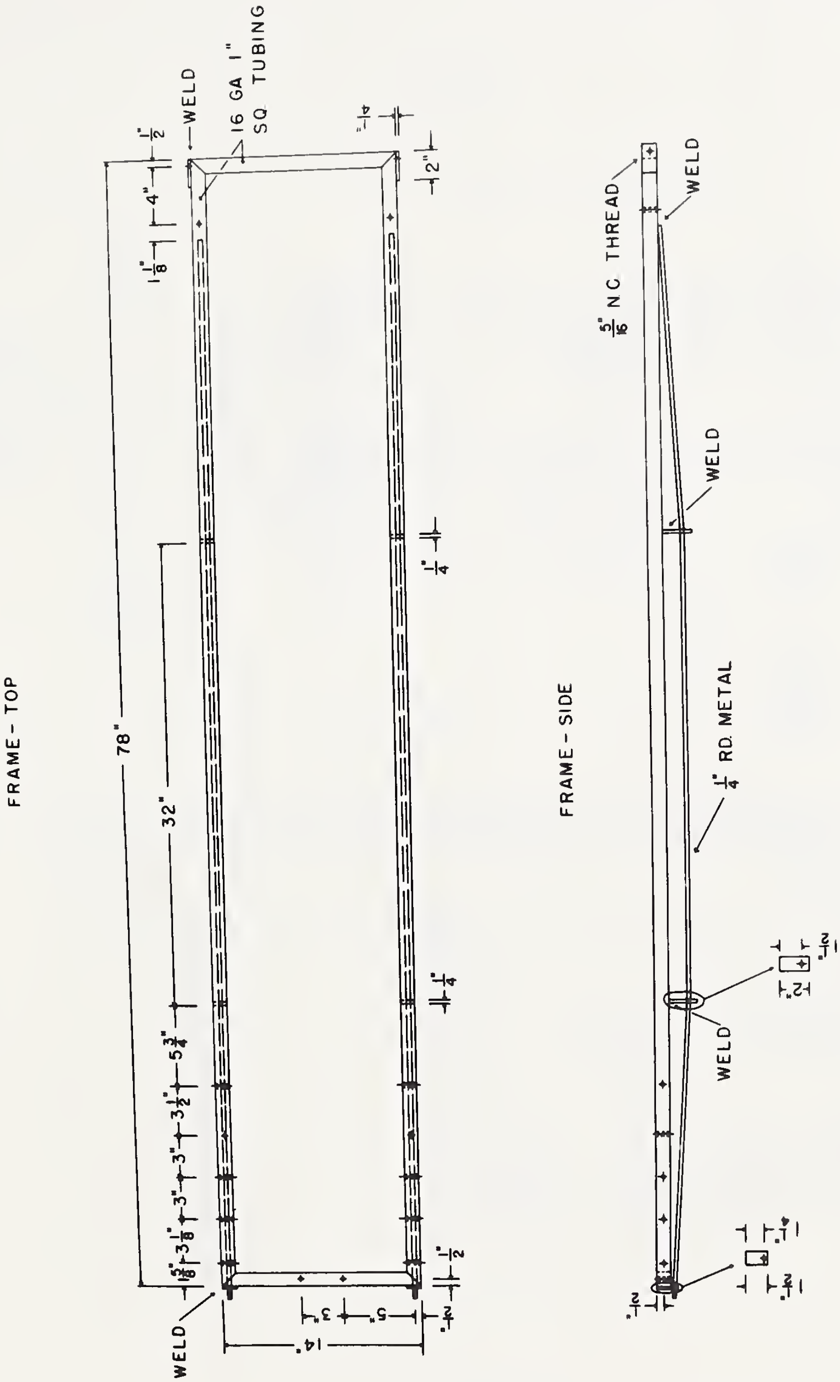
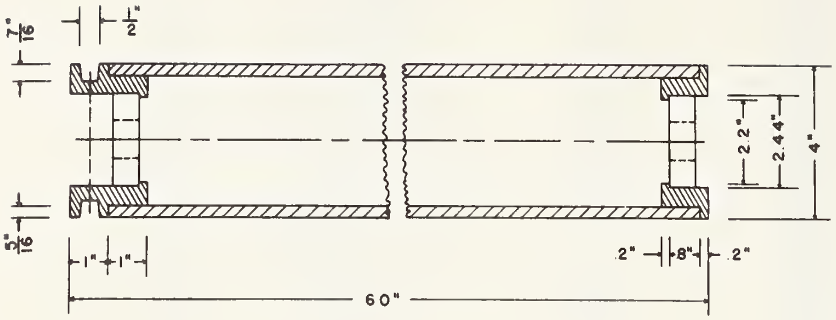

FRAME - TOP
FRAME - SIDE
16 GA 1" SQ. TUBING
WELD
78"
32"
14"
5/16" N.C. THREAD
1/4" RD. METAL

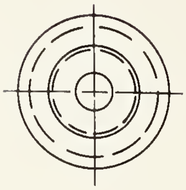
PLATE 5

ROLLS

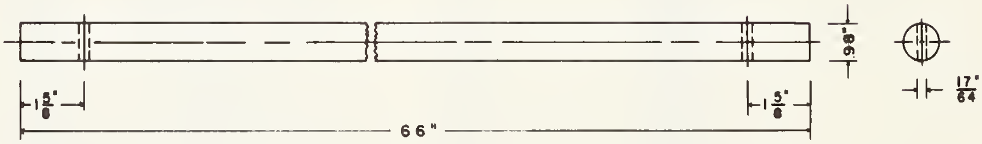
ROLL CROSS SECTION

END VIEW





SHAFT



BEARING

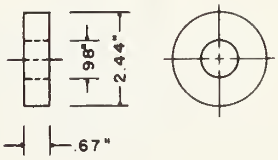


PLATE 6

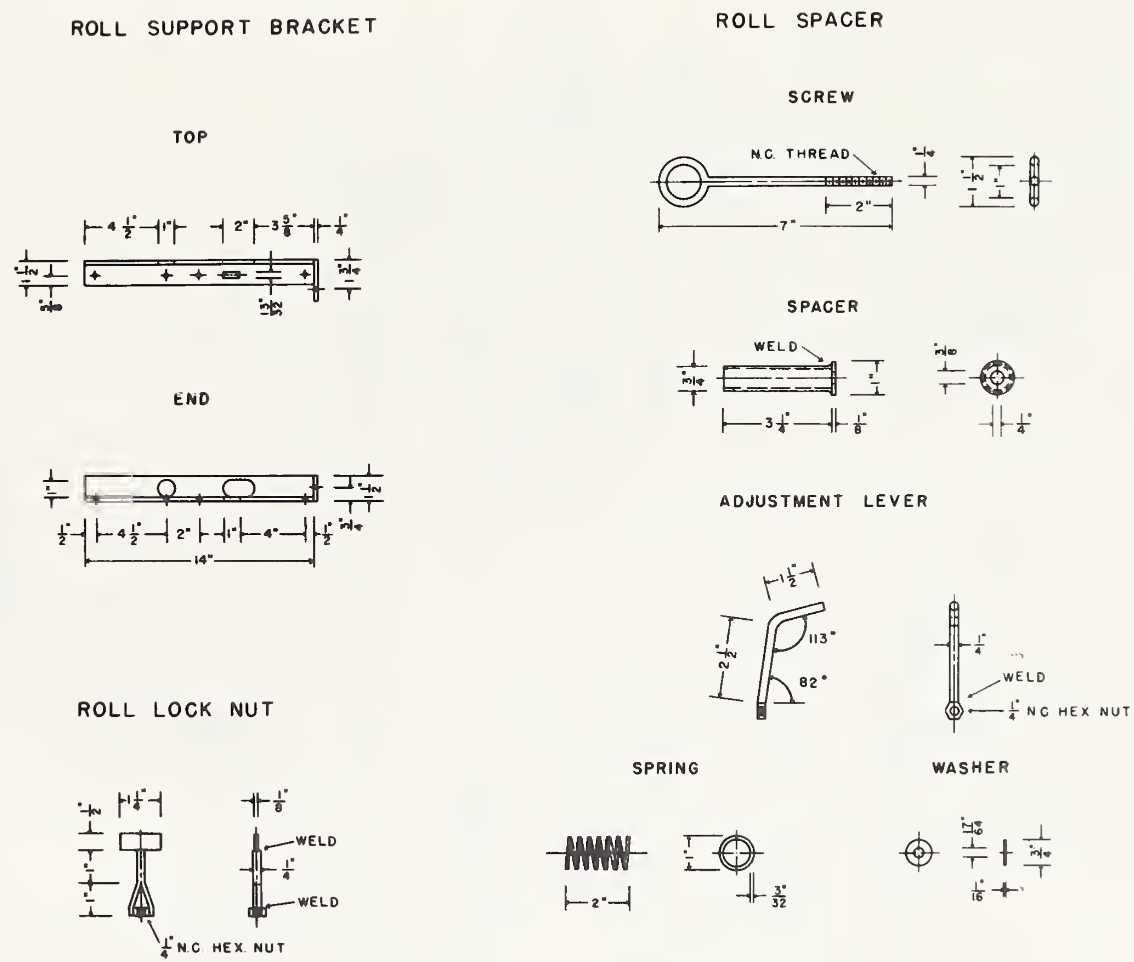
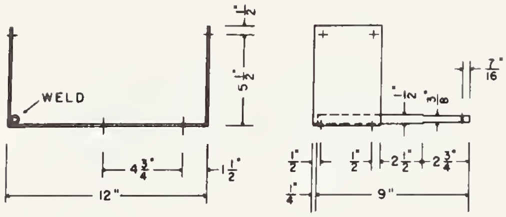
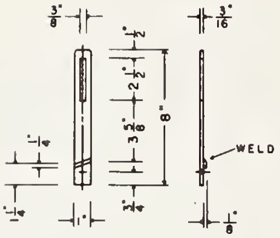

ROLL SUPPORT BRACKET
TOP
END
14"
ROLL LOCK NUT
WELD
WELD
1/4" N.C. HEX. NUT
ROLL SPACER
SCREW
N.C. THREAD
2"
7"
SPACER
WELD
ADJUSTMENT LEVER
113°
82°
WELD
1/4" N.C. HEX NUT
SPRING
2"
3/32"
WASHER

PLATE 7

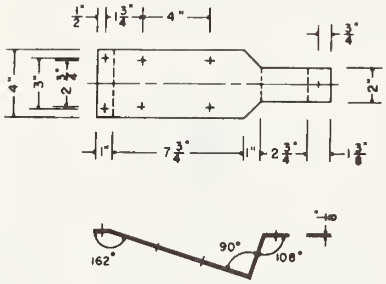
MOTOR MOUNT



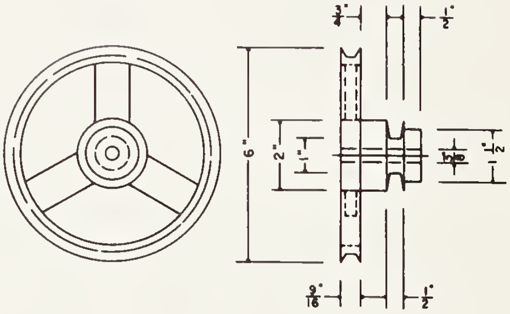
IDLE ARM



VIBRATOR FRAME



DRIVE PULLEY



IDLE PULLEY

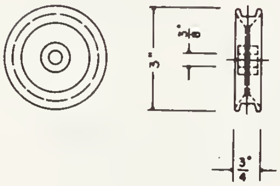


PLATE 8

MAIN SUPPORT FRAME

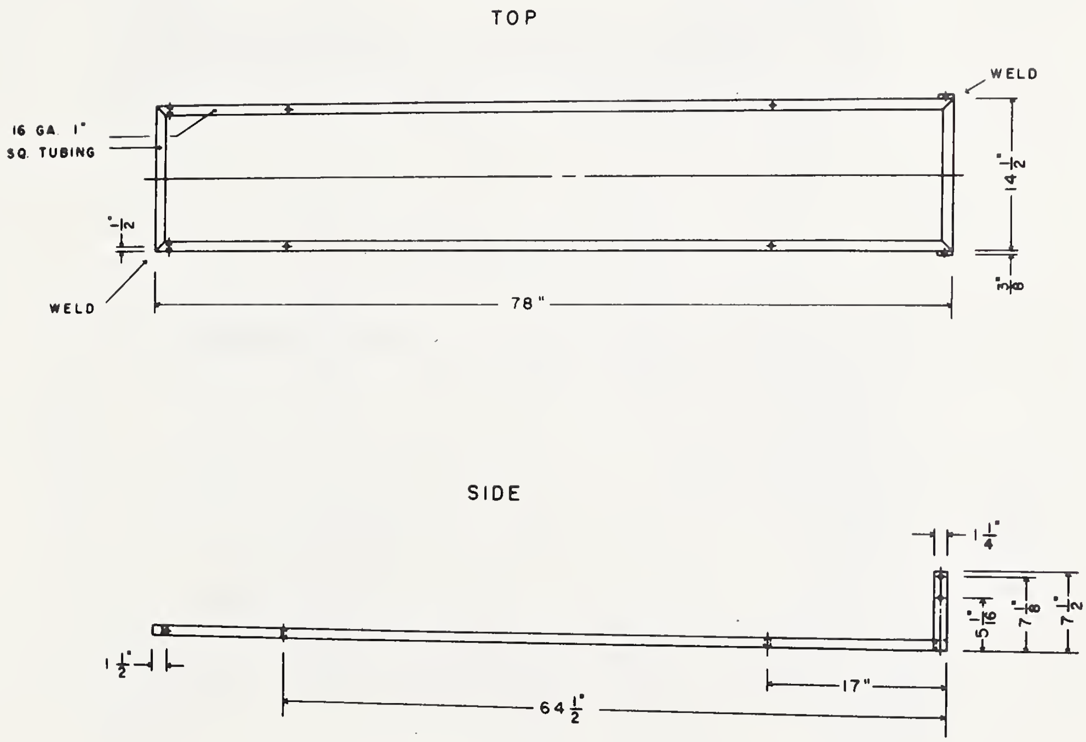


PLATE 9

SUPPORT BRACKET

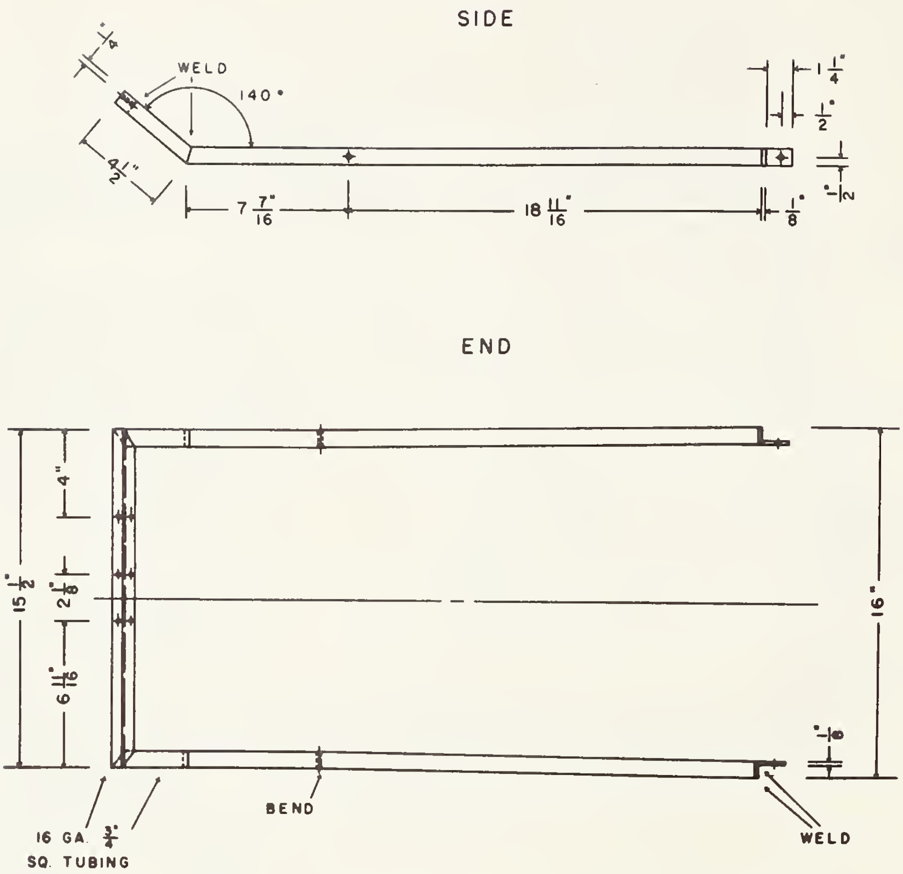
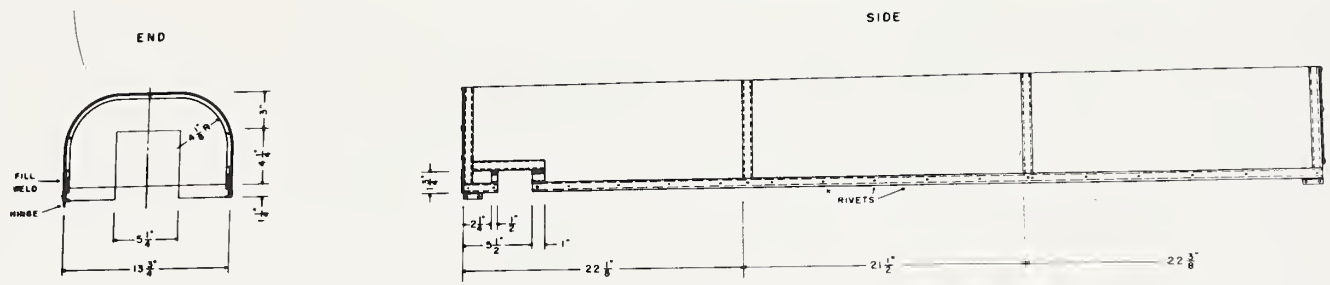
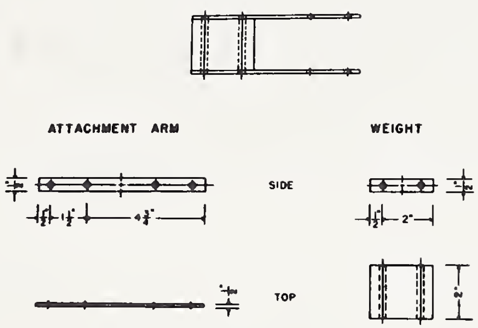


PLATE 10

COVER



VIBRATOR WEIGHT ASSEMBLY



TRAY PATTERN

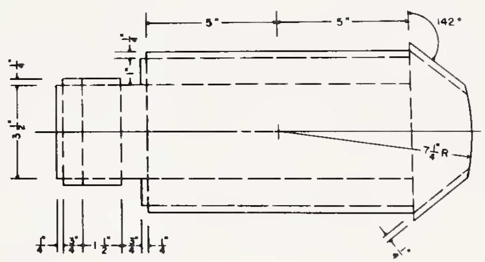


PLATE 11